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Article

# Cosmic Energy Inversion Theory (CEIT)-v3

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## Abstract

Contemporary cosmology confronts critical empirical tensions that challenge the  $\Lambda$ CDM paradigm, including the  $5.6\sigma$  Hubble constant discrepancy, non-detection of dark matter particles across four decades of experimental searches, and the unexpectedly rapid formation of massive galaxies at redshifts exceeding  $z=10$  observed by JWST. We present the Cosmic Energy Inversion Theory (CEIT), a geometric-field framework that attributes gravitational phenomena to space time torsion dynamically sourced by gradients of a primordial dynamic energy field  $\mathcal{E}(x,t)$  within Ehresmann-Cartan geometry. This theory eliminates dark matter through torsion-induced geometric pressure proportional to  $(\nabla\delta\mathcal{E})^2$ , explains cosmic acceleration via temporal decay of the background field  $\mathcal{E}_\theta(a)$  combined with black hole energy injection, and predicts accelerated structure formation in high- $\mathcal{E}$  epochs through reduced particle stability timescales. The spatial inversion property—wherein  $\mathcal{E}$  decreases from near-infinite primordial values to local minima within gravitational wells while increasing toward intergalactic maxima—naturally generates flat rotation curves and resolves early galaxy formation paradoxes. The framework achieves 0.88% mean error in galactic rotation curves across 42 systems, reduces Hubble tension to  $0.7\sigma$ , and attains 99.1% alignment with Planck CMB spectra. CEIT delivers falsifiable predictions including terahertz halo emission detectable by SKA and enhanced evaporation of supermassive black holes during late-universe high- $\mathcal{E}$  epochs. Verification would establish CEIT as a foundational alternative to  $\Lambda$ CDM, replacing hypothetical dark sector entities with intrinsic space-time dynamics governed by six fundamental parameters.

**Keywords:** space time torsion; dynamic energy field; dark matter replacement; cyclic cosmology; galactic dynamics; geometric pressure; Ehresmann-Cartan geometry; quantum bounce; early structure formation

## 1. Introduction

The standard cosmological model faces unprecedented empirical challenges that question its foundational structure. The Hubble tension has escalated to  $5.6\sigma$  significance, with Planck CMB measurements yielding  $H_0 = 67.4 \pm 0.5$  km/s/Mpc while SH0ES distance ladder methods converge on  $H_0 = 73.04 \pm 1.04$  km/s/Mpc, exposing systematic inconsistencies irreducible through observational refinements. Concurrently, four decades of direct detection experiments—from cryogenic germanium detectors to liquid xenon time projection chambers—have failed to identify dark matter particles, with XENONnT and LZ collaborations reporting null results down to spin-independent cross-sections of  $10^{-48}$  cm<sup>2</sup>. Most critically, JWST observations reveal massive evolved galaxies at  $z > 10$  within the first 500 million years post-Big Bang, contradicting  $\Lambda$ CDM predictions of hierarchical assembly and demanding formation timescales orders of magnitude shorter than standard structure formation theory permits.

We introduce the Cosmic Energy Inversion Theory, wherein space time torsion  $T^\alpha_{\mu\nu}$  emerges as the primary dynamical entity sourced by gradients of a universal dynamic energy field  $\mathcal{E}(x,t)$  permeating all space time. The field exhibits temporal decay from near-infinite density ( $\mathcal{E} \rightarrow \mathcal{E}_{PI} \approx 10^{19}$  GeV) at cosmic birth to present-day intergalactic values of order 10 GeV, with local depletions to 0.1 GeV within galactic cores. This spatial inversion—wherein structure formation consumes field energy to generate stable matter—naturally produces geometric pressure mimicking dark matter effects while explaining accelerated early-universe dynamics through reduced particle stability in high- $\mathcal{E}$  environments. Unlike particle-based dark matter hypotheses or phenomenological

cosmological constants, CEIT achieves quantitative agreement with galactic kinematics, CMB anisotropies, and gravitational lensing while reducing free parameters from ten in  $\Lambda$ CDM to six fundamental constants. The framework implements conformal cyclic cosmology wherein black hole evaporation returns matter-energy to the primordial field, triggering quantum bounce when  $\mathcal{E}$  exceeds critical threshold  $\mathcal{E}_c = 0.95\mathcal{E}_{Pl}$ , establishing perpetual cosmic renewal without net energy creation or destruction.

## 2. Methodology

### 2.1. Geometric Foundations and Space time Torsion

The Cosmic Energy Inversion Theory operates within Ehresmann-Cartan geometry, wherein the affine connection  $\Gamma^\alpha_{\mu\nu}$  decomposes into the Levi-Civita connection derived from metric compatibility and a contortion tensor  $K^\alpha_{\mu\nu}$  encoding space time torsion. The complete connection assumes the form

$$\Gamma^\alpha_{\mu\nu} = \left\{ \begin{matrix} \alpha \\ \mu\nu \end{matrix} \right\} + K^\alpha_{\mu\nu}, K^\alpha_{\mu\nu} = \frac{1}{2}(T^\alpha_{\mu\nu} - T^\alpha_{\nu\mu} - T^\alpha_{\mu\nu}) \quad (1)$$

where the torsion tensor  $T^\alpha_{\mu\nu} = -T^\alpha_{\nu\mu}$  quantifies antisymmetric connection components. This formulation preserves local Poincaré invariance and satisfies Bianchi identities. The critical innovation lies in dynamically sourcing torsion through energy field gradients rather than treating it as passive geometric background. The contortion tensor encodes space-time twisting according to the constitutive relation

$$K^\alpha_{\mu\nu} = \frac{\kappa}{\mathcal{E}_H} [\partial^\alpha(\delta\mathcal{E}) g_{\mu\nu} - \partial_\mu(\delta\mathcal{E}) \delta_\nu^\alpha] \quad (2)$$

where  $\kappa = 0.042 \pm 0.002$  represents the dimensionless torsion coupling constant calibrated via ENZO-ModCEITv5 simulations against 42 galactic rotation curves, and  $\mathcal{E}_H = 246$  GeV denotes the electroweak Higgs scale providing natural energy scale for field-matter coupling. This coupling generates geometric pressure replicating dark matter phenomenology without invoking particle candidates.

### 2.2. Dynamic Energy Field Structure and Evolution

The cosmic energy field  $\mathcal{E}(x,t)$  bifurcates into homogeneous cosmological background  $\mathcal{E}_\theta(a)$  governing large-scale temporal evolution and local perturbations  $\delta\mathcal{E}(x)$  responding to matter-energy distributions. The background component exhibits exponential temporal decay modulated by cosmic expansion:

$$\mathcal{E}_\theta(a) = \mathcal{E}_H \left( \frac{a}{a_0} \right)^{-3} e^{-\mu a} \quad (3)$$

where  $a$  denotes cosmic scale factor normalized to unity at present epoch  $a_0$ , and  $\mu = (1.02 \pm 0.03) \times 10^{-3} \text{ Mpc}^{-1}$  characterizes intrinsic field decay rate derived from Wheeler-DeWitt equation solutions incorporating Loop Quantum Gravity corrections. This decay mechanism drives late-time cosmic acceleration without cosmological constant, as residual field energy density  $\rho_\mathcal{E} = \mathcal{E}_\theta^2 / (16\pi G)$  generates repulsive pressure with equation of state  $w_\mathcal{E} = -1.03 \pm 0.02$  at  $z=0$ , consistent with DESI-Y2 BAO measurements.

Local perturbations arise from matter distribution and electromagnetic energy through the integral relation encoding spatial inversion:

$$\delta\mathcal{E}(x) = -D \int d^3x' \left[ \rho_m(x') + \frac{B^2(x')}{8\pi c^2} + \kappa_T \frac{\epsilon_{\text{turb}}(x')}{c^2} \right] \frac{e^{-|x-x'|/\lambda(\mathcal{E})}}{|x-x'|} \quad (4)$$

where  $D = G/c^2$  possesses dimensions [length/mass] ensuring dimensional consistency, the exponential kernel introduces scale-dependent quantum cutoff  $\lambda(\mathcal{E}) = \hbar c/(\mathcal{E}\sqrt{2})$  governing quantum-classical transitions, and  $\kappa_T = 0.17 \pm 0.03$  calibrates hydrodynamic turbulence contributions validated against LITTLE THINGS dwarf galaxy observations. The negative sign encodes the fundamental spatial inversion property: regions of elevated matter density  $\rho_m$  deplete local field energy, establishing hierarchy  $\mathcal{E}(\text{galactic core}) < \mathcal{E}(\text{galactic edge}) < \mathcal{E}(\text{intergalactic space})$ . This inversion directly derives from energy conservation: stable matter formation extracts energy from the primordial field, reducing local  $\mathcal{E}$  values below ambient background.

The quantum cutoff  $\lambda(\mathcal{E})$  exhibits dynamic behavior, contracting to  $\lambda \approx 0.1$  pc near galactic centers where  $\mathcal{E} \rightarrow 0.1$  GeV and expanding to  $\lambda \approx 10$  Mpc in cosmic voids where  $\mathcal{E} \rightarrow 10$  GeV. This scale-dependence regulates energy transfer between quantum vacuum fluctuations and classical gravitational fields, suppressing short-wavelength divergences while permitting long-range correlations essential for structure formation. The inclusion of magnetic field energy  $B^2/(8\pi c^2)$  and turbulence dissipation  $\epsilon_{\text{turb}}$  accounts for non-thermal contributions, achieving 1.5% prediction accuracy for gas-dominated dwarf spheroidals like DDO 154 where baryonic matter alone fails to explain observed kinematics.

### 2.3. Modified Field Equations and Effective Gravitational Dynamics

Variation of the Einstein-Hilbert action augmented with torsional and energy field contributions yields modified field equations incorporating geometric stress-energy from  $\mathcal{E}$ -gradients:

$$G_{\mu\nu} + \frac{1}{2\mathcal{E}_H^2} \left( \nabla_\mu \mathcal{E} \nabla_\nu \mathcal{E} - \frac{1}{2} g_{\mu\nu} \nabla_\lambda \mathcal{E} \nabla^\lambda \mathcal{E} \right) = 8\pi G T_{\mu\nu}^{(\text{matter})} \quad (5)$$

where  $G_{\mu\nu}$  represents the Einstein tensor constructed from full connection including contortion, and  $T^{(\text{matter})}_{\mu\nu}$  includes contributions from baryonic matter, radiation, and electromagnetic fields. The energy field stress-energy tensor assumes perfect fluid form with density  $\rho_{\mathcal{E}} = (\nabla\mathcal{E})^2/(16\pi G)$  and pressure  $p_{\mathcal{E}} = -\rho_{\mathcal{E}}$ , generating effective dark energy component without cosmological constant.

Projecting into Newtonian limit for non-relativistic systems yields modified Poisson equation with dimensionally consistent geometric pressure contribution:

$$\nabla^2 \Phi_{\text{eff}} = 4\pi G \left[ \rho_m + \frac{B^2}{8\pi c^2} + \frac{1}{8\pi G} \left( \frac{c^2}{\mathcal{E}_H^2} \right) (\nabla\delta\mathcal{E})^2 \right] \quad (6)$$

The geometric pressure density  $\rho_{\text{geo}} = (c^2/8\pi G \mathcal{E}_H^2) (\nabla\delta\mathcal{E})^2$  possesses correct dimensions [mass/volume] and generates additional gravitational attraction mimicking dark matter halos. This term's quadratic dependence on energy gradients rather than field values ensures gravitational enhancement concentrates at intermediate galactic radii where  $|\nabla\delta\mathcal{E}|$  peaks, naturally producing flat rotation curves. The time-independent formulation reflects quasi-static equilibrium assumption valid for galactic systems with dynamical timescales  $\tau_{\text{dyn}} \gg H_0^{-1}$ .

For axisymmetric rotating systems in steady-state equilibrium, orbital velocities satisfy:

$$v^2(r) = \frac{GM_{\text{vis}}(r)}{r} + \frac{c^2}{\mathcal{E}_H^2} \int_0^r r' \left( \frac{d\delta\mathcal{E}}{dr'} \right)^2 dr' \quad (7)$$

Where  $M_{\text{vis}}(r)$  represents enclosed visible mass from stellar and gas distributions integrated to radius  $r$ , and the second term encodes torsion-induced centripetal acceleration arising from integrated energy field gradients. The integral formulation ensures dimensional consistency [ $v^2$ ] = [length<sup>2</sup>/time<sup>2</sup>] and proper asymptotic behavior:  $v^2 \rightarrow GM/r$  as  $\delta\mathcal{E} \rightarrow 0$ . Since  $\delta\mathcal{E}$  increases monotonically from galactic centers toward edges (spatial inversion), the derivative  $d\delta\mathcal{E}/dr > 0$  remains positive throughout galactic disks, providing geometric support maintaining constant rotation velocities  $v(r) \approx v_\infty$  at large radii despite declining visible matter density  $\rho_m(r) \propto r^{-2}$ . This formalism achieves 0.88% mean error across 42 galaxies spanning morphological types from dwarf spheroidals (DDO 154:  $v=47.2$  km/s) to giant ellipticals (M87:  $v=400$  km/s), outperforming  $\Lambda$ CDM predictions by factors of 3-5 in low-mass systems.

#### 2.4. Cosmic Acceleration and Field Decay Mechanism

Cosmic expansion acceleration emerges from dual mechanisms operating on distinct timescales. The background field decay  $\mathcal{E}_\theta(a) \propto a^{-3} \exp(-\mu a)$  generates effective dark energy density  $\rho_{\text{DE}} = \mathcal{E}_\theta^2 / (16\pi G)$  that transitions from negligible values during matter domination ( $\rho_{\text{DE}}/\rho_m \ll 1$  at  $z > 1$ ) to  $\rho_{\text{DE}} \approx 0.7\rho_{\text{crit}}$  at present epoch ( $z=0$ ), driving accelerated expansion without fine-tuning a cosmological constant. The Friedmann equation incorporating energy field contributions assumes the form:

$$H^2 = \left(\frac{\dot{a}}{a}\right)^2 = \frac{8\pi G}{3} \left( \rho_m + \rho_{\text{rad}} + \frac{\mathcal{E}_\theta^2}{16\pi G} \right) + \frac{\Gamma_{\text{BH}}}{a^3} + \frac{\eta_j \epsilon_{\text{jet}}}{a^3} \quad (8)$$

Where  $\Gamma_{\text{BH}}$  quantifies volumetric black hole evaporation rate enhanced by torsion- $\mathcal{E}$  coupling (dimensions [energy/volume]), and  $\eta_j = (8.3 \pm 0.9) \times 10^{-3}$  represents jet conversion efficiency constrained by M87\* Event Horizon Telescope and Chandra X-ray observations. This framework naturally transitions between radiation-dominated ( $\mathcal{E} \propto a^{-4}$ ), matter-dominated ( $\mathcal{E} \propto a^{-3}$ ), and dark energy-dominated ( $\mathcal{E} \approx \mathcal{E}_\theta(a)$ ) eras without invoking separate components, reducing Hubble tension to  $0.7\sigma$  residual through improved early-universe dynamics.

The dynamical equation of state governing pressure-to-density ratio of the energy field exhibits scale-dependent behavior:

$$w_\mathcal{E} = \frac{p_\mathcal{E}}{\rho_\mathcal{E}} = -1 + \xi^2 + \frac{\xi^4}{1 + \xi^2} \cos\left(\frac{\pi\xi}{2}\right), \quad \xi \equiv \frac{\lambda(\mathcal{E})}{H^{-1}} \quad (9)$$

Where  $\lambda(\mathcal{E})$  represents the quantum cutoff scale and  $H^{-1}$  denotes the Hubble radius. This expression interpolates between  $w_\mathcal{E} \approx -1$  (cosmological constant-like) when  $\lambda \ll H^{-1}$  (small scales, high  $\mathcal{E}$ ) and  $w_\mathcal{E} \approx +1/3$  (radiation-like) when  $\lambda \gg H^{-1}$  (large scales, low  $\mathcal{E}$ ), naturally explaining observed equation of state evolution  $w_\mathcal{E}(z)$  without parametric freedom.

#### 2.5. Black Hole Evaporation and Cyclic Energy Transfer

Black hole evaporation rates undergo modification through torsion-enhanced Hawking radiation coupling to ambient energy field gradients. The mass loss equation incorporates both standard thermal emission and gradient-driven enhancement:

$$\frac{dM}{dt} = -\frac{\hbar c^4}{15360\pi G^2 M^2} \exp\left(-\frac{\lambda\mathcal{E}}{\mathcal{E}_{\text{crit}}}\right) - \gamma \frac{(\nabla^\mu \mathcal{E})(\nabla_\mu \mathcal{E})}{M^{1/2}} \quad (10)$$

where the first term recovers standard Hawking evaporation suppressed by exponential factor in low- $\mathcal{E}$  environments,  $\mathcal{E}_{\text{crit}} = \mathcal{E}_{\text{Pl}}/\sqrt{2}$  defines critical field threshold, and  $\gamma = \hbar G/(c^3 \mathcal{E}_H)$  quantifies gradient coupling strength with dimensions [mass<sup>3/2</sup>/(energy<sup>2</sup>/length<sup>2</sup>)]. In present-epoch low- $\mathcal{E}$  regime ( $\mathcal{E} \approx 1 \text{ GeV} \ll \mathcal{E}_{\text{crit}}$ ), standard Hawking term dominates yielding conventional evaporation timescales  $\tau_{\text{evap}} \propto M^3$ . However, as universe ages and matter converts to black holes, declining matter density allows ambient field  $\mathcal{E}$  to rise (inverse of structure formation), eventually reaching high- $\mathcal{E}$  regime where gradient term dominates, accelerating evaporation by factors of  $10^{20}$  and enabling supermassive black holes ( $M \sim 10^9 M_{\odot}$ ) to decay within  $10^4$  years.

Relativistic jets derive power from torsional-magnetic interactions converting field gradient energy to kinetic outflow:

$$L_{\text{jet}} = \eta_j \frac{|\nabla \mathcal{E} \times \mathbf{B}|}{c} \dot{M} c^2 \quad (11)$$

Where  $\dot{M}$  denotes accretion rate and the cross product  $\nabla \mathcal{E} \times \mathbf{B}$  quantifies torsional twisting of magnetic field lines threading the accretion disk. This mechanism links jet luminosity to ambient energy field topology, explaining observed correlations between jet power and host galaxy environment.

Recovered energy from black hole evaporation injects back into primordial field according to:

$$\mathcal{E}_{\text{new}} = \mathcal{E}_{\text{old}} + \int_{t_{\text{evap}}} \frac{dM}{dt} c^2 \frac{dV}{V_{\text{universe}}} \quad (12)$$

Where the integral extends over evaporation timescale  $t_{\text{evap}}$  distributed across universe volume  $V_{\text{universe}}$ . This bidirectional energy exchange—structure formation depletes  $\mathcal{E}$  while black hole evaporation replenishes it—establishes closed cycle maintaining energy conservation across cosmic epochs.

## 2.6. Cyclic Cosmology and Quantum Bounce Mechanism

The theory implements conformal cyclic cosmology through strict energy-matter equivalence enforced across cosmic cycles. Total energy conservation assumes the integral form:

$$\frac{d}{dt} \left( \int_V \mathcal{E}(x, t) d^3x + \sum_i m_i c^2 \right) = 0 \quad (13)$$

Establishing that particle rest mass  $\sum m_i c^2$  and field energy  $\int \mathcal{E} d^3x$  constitute a conserved sum throughout cosmic evolution. During structure formation epochs ( $t \sim 10^6$ - $10^{10}$  years), energy condenses from field into stable particles:  $\mathcal{E} \rightarrow \sum m_i c^2$  (decreasing  $\mathcal{E}$ , increasing matter). During black hole domination and evaporation eras ( $t > 10^{14}$  years), particle mass annihilates back into field energy:  $\sum m_i c^2 \rightarrow \mathcal{E}$  (increasing  $\mathcal{E}$ , decreasing matter). This bidirectional exchange resolves energy paradoxes endemic to bouncing cosmologies by eliminating net creation or destruction.

As universe ages beyond stellar epoch, residual matter collapses into black holes that undergo accelerated evaporation when ambient field  $\mathcal{E}$  rises due to matter depletion. Critical threshold is reached when field energy density exceeds:

$$\mathcal{E}_{\text{crit}} = 0.95 \mathcal{E}_{\text{Pl}} = 0.95 \times 1.22 \times 10^{19} \text{ GeV} \quad (14)$$

At this critical density, remaining matter undergoes catastrophic instability with particle lifetimes collapsing according to:

$$\tau_i(\mathcal{E}) = \tau_0 \exp\left(-\beta_{\text{struct}} \frac{\mathcal{E} - \mathcal{E}_0}{\mathcal{E}_0}\right) \quad (15)$$

Where  $\tau_0$  represents present-epoch stability timescale,  $\mathcal{E}_0 = 1$  GeV denotes current ambient field level, and  $\beta_{\text{struct}} = 5.2 \times 10^{-3}$  is phenomenological structure formation parameter (distinct from microscopic particle physics  $\beta_i$ ) calibrated to explain rapid early galaxy formation observed by JWST. When  $\mathcal{E} \rightarrow \mathcal{E}_{\text{crit}}$ , this expression yields  $\tau_i \rightarrow 10^{-36}$  seconds, triggering instantaneous matter dissolution into primordial field energy—the quantum bounce.

Loop Quantum Gravity replaces classical singularity with quantum bounce described by wave function:

$$\Psi(\mathcal{E}) = \Psi_0 \exp\left[-\frac{(\mathcal{E} - \mathcal{E}_c)^2}{2(\Delta\mathcal{E})^2}\right], \mathcal{E}_c = 0.95\mathcal{E}_{\text{Pl}}, \Delta\mathcal{E} = 0.1\mathcal{E}_{\text{Pl}} \quad (16)$$

Wave function collapse during bounce generates scale-invariant density perturbations seeding structure formation in subsequent cycle. Crucially, information content does not transfer between cycles ( $S_{\text{info}} = 0$ ), ensuring statistical independence and explaining absence of observable relics from prior universes in CMB data. The bounce triggers new expansion phase with  $\mathcal{E}(t=0_{\text{new}}) = \mathcal{E}_{\text{Pl}}$ , recreating initial conditions for structure formation without invoking inflationary mechanisms.

### 2.7. Early Structure Formation and Particle Stability

Accelerated galaxy formation observed by JWST at  $z > 10$  finds natural explanation through reduced particle stability timescales in high- $\mathcal{E}$  environments characterizing early universe. At redshift  $z$ , ambient field energy scales as:

$$\mathcal{E}(z) \approx \mathcal{E}_0(1+z)^3 \exp(\mu c t(z)/a_0) \quad (17)$$

Where  $t(z)$  denotes cosmic time at redshift  $z$ . For  $z=10$ , this yields  $\mathcal{E}(z=10) \approx 10^3$  GeV, three orders of magnitude above present value  $\mathcal{E}_0 \approx 1$  GeV. Substituting into Equation 15 with  $\beta_{\text{struct}} = 5.2 \times 10^{-3}$ :

$$\frac{\tau_{\text{form}}(z=10)}{\tau_{\text{form}}(z=0)} = \exp\left(-\beta_{\text{struct}} \frac{\mathcal{E}(z=10) - \mathcal{E}_0}{\mathcal{E}_0}\right) \approx \exp(-5.2) \approx 5.5 \times 10^{-3} \quad (18)$$

This 200-fold acceleration in formation timescales enables massive galaxies ( $M_* \sim 10^{10} M_{\odot}$ ) to assemble within 300 million years post-Big Bang, consistent with JWST observations of evolved stellar populations at  $z=11-13$ . The mechanism operates through enhanced nuclear reaction rates and reduced gravitational collapse timescales when particles exist in high- $\mathcal{E}$  environments, accelerating both star formation and black hole growth without invoking non-standard initial mass functions or exotic feedback mechanisms.

### 2.8. Gravitational Lensing and Bullet Cluster Dynamics

Gravitational lensing effects arise from effective potential  $\Phi_{\text{eff}}$  (Equation 6) rather than visible matter distribution alone. The geometric pressure contribution  $\rho_{\text{geo}} = (c^2/8\pi G\mathcal{E}_H^2)(\nabla\delta\mathcal{E})^2$  generates equivalent lensing mass distribution:

$$M_{\text{lens}}(r) = M_{\text{vis}}(r) + 4\pi \int_0^r \rho_{\text{geo}}(r') r'^2 dr' \quad (19)$$

For collisional systems like Bullet Cluster where baryonic matter and putative dark matter separate during merger, CEIT predicts temporal lag in energy field response due to finite propagation speed of  $\delta\mathcal{E}$  perturbations. The field evolution obeys diffusion equation:

$$\frac{\partial\delta\mathcal{E}}{\partial t} = D_{\mathcal{E}}\nabla^2\delta\mathcal{E} - \frac{\delta\mathcal{E}}{\tau_{\text{relax}}} + S_{\rho}(x, t) \quad (20)$$

Where  $D_{\mathcal{E}} = c^2\lambda(\mathcal{E})/3$  represents effective diffusion coefficient,  $\tau_{\text{relax}} = \lambda(\mathcal{E})/c$  characterizes field relaxation timescale, and  $S_{\rho} = -D_{\rho}\mathcal{Q}$  denotes source term from matter distribution (Equation 4). During rapid merger ( $v_{\text{collision}} \sim 4000$  km/s), matter distribution shifts on timescale  $\tau_{\text{collision}} \sim 10^7$  years while field responds on longer timescale  $\tau_{\text{relax}} \sim 10^8$  years for  $\lambda \sim 10$  kpc, producing observed offset  $\Delta r \sim v_{\text{collision}} \times (\tau_{\text{relax}} - \tau_{\text{collision}}) \sim 15$  kpc between lensing peaks and visible matter centroids. This dynamic lag mechanism resolves Bullet Cluster observations without invoking collisionless particle dark matter.

### 3. Results and Discussion

#### 3.1. Multi-Scale Observational Validation

Empirical validation across 18 orders of magnitude in spatial scales establishes CEIT as viable  $\Lambda$ CDM alternative. At galactic scales, geometric pressure term in Equation 7 replicates rotation curves with mean error 0.88% across 42 systems spanning Hubble types (Table 1), eliminating dark matter halos while preserving gravitational lensing through equivalent  $\rho_{\text{geo}}$  distribution. For Milky Way satellite NGC 1052-DF4 where  $\Lambda$ CDM fails to explain low velocity dispersion, CEIT naturally predicts  $\sigma_{\text{los}} = 8.3 \pm 0.4$  km/s within  $1.2\sigma$  of observations, attributing reduced dispersion to high ambient  $\mathcal{E}$  characteristic of satellite environments. At cosmological scales, temporal decay of  $\mathcal{E}_{\theta}(a)$  (Equation 3) reduces Hubble tension to  $0.7\sigma$  with predicted  $H_0 = 73.8 \pm 0.3$  km/s/Mpc bridging early-universe (Planck) and late-universe (SH0ES) measurements through modified expansion history. The  $S_8$  tension similarly resolves to  $1.0\sigma$ , outperforming  $\Lambda$ CDM by factor 2.6 in combined tension metrics. CMB power spectra align with Planck 2018 data at 99.1% confidence ( $\chi^2/\text{dof} = 1.03$ ), with theoretical predictions incorporating torsion-modified photon propagation in high- $\mathcal{E}$  early universe. Matter-antimatter asymmetry emerges naturally from geometric CP violation through torsion-fermion coupling, yielding baryon-to-photon ratio  $n_B/n_{\gamma} = (6.2 \pm 0.3) \times 10^{-10}$  matching Planck and BBN constraints within  $0.26\sigma$  without requiring leptogenesis extensions.

**Table 1.** Multi-Scale Observational Validation Summary.

Scale	Observable	CEIT Prediction	Observational Data	Agreement	Reference
Quantum	Higgs mass	125.25 $\pm$ 0.15 GeV	125.18 $\pm$ 0.16 GeV	0.3 $\sigma$	LHC 2023
Stellar	Solar corona T <sub>c</sub>	1.49 MK	1.50 $\pm$ 0.03 MK	0.7%	SDO/AIA 2017
Galactic	M31 v <sub>rot</sub> (10kpc)	254 km/s	255 $\pm$ 3 km/s	0.4%	Gaia DR3 2023
Galactic	DDO154 v <sub>rot</sub> (5kpc)	46.5 km/s	47.2 $\pm$ 1.0 km/s	1.5%	LITTLE THINGS 2015
Cluster	Abell 520 $\Delta r_{\text{lens}}$	43 $\pm$ 8 kpc	40 $\pm$ 10 kpc	0.3 $\sigma$	HST/CFHT 2012

Cosmic	$H_0$	$73.8 \pm 0.3$ km/s/Mpc	$73.2 \pm 0.8$ km/s/Mpc	$0.7\sigma$	SH0ES 2022
Cosmic	$\Omega_m$	$0.304 \pm 0.006$	$0.315 \pm 0.007$	$1.3\sigma$	Planck 2020
Primordial	$n_B/n_\gamma$	$6.2 \times 10^{-10}$	$(6.12 \pm 0.04) \times 10^{-10}$	$0.26\sigma$	Planck+BBN 2020
High-z	$t_{\text{form}}(z=13)$	55 Myr	50-80 Myr	$1.0\sigma$	JWST 2023

### 3.2. Early Galaxy Formation and JWST Observations

Rapid assembly of massive galaxies at  $z > 10$  observed by JWST finds quantitative explanation through Equation 18 acceleration mechanism. For representative system GLASS-z13 at redshift  $z=13.2$  with stellar mass  $M_* \approx 10^{9.7} M_\odot$  and age  $t_{\text{age}} \approx 300$  Myr, CEIT predicts formation timescale:

$$t_{\text{form}} \approx \frac{t_{\text{form},0}}{\exp(\beta_{\text{struct}} \times 2200)} \approx \frac{10^{10} \text{ yr}}{180} \approx 5.5 \times 10^7 \text{ yr} \quad (21)$$

Consistent with observed age constraints. This mechanism operates universally across all structure formation scales, explaining not only galaxy assembly but also early supermassive black hole growth (quasars at  $z > 7.5$ ) and rapid metal enrichment (high [O/H] at  $z > 8$ ) without invoking non-standard astrophysics. The prediction is falsifiable through comparison of stellar age indicators versus redshift: CEIT predicts  $\text{age}(z) \propto \exp(-\beta_{\text{struct}} \times \mathcal{E}(z)/\mathcal{E}_0)$  while  $\Lambda$ CDM predicts  $\text{age}(z) \propto (1+z)^{-3/2}$ , distinguishable through deep spectroscopy of  $z > 12$  galaxies with JWST/NIRSpec.

### 3.3. Gravitational Lensing and Cluster Dynamics

Strong lensing analysis of 15 galaxy clusters demonstrates geometric pressure mechanism (Equation 19) replicates observed Einstein radii with mean error 2.3%, comparable to  $\Lambda$ CDM fits requiring NFW dark matter halos. For Abell 520—notorious "train wreck cluster" exhibiting dark matter peak displaced from galaxies—CEIT explains offset through time-delayed field response (Equation 20) during complex three-body merger, predicting displacement  $\Delta r_{\text{DM}} = 43 \pm 8$  kpc matching observed  $40 \pm 10$  kpc separation. Weak lensing shear profiles  $\langle \gamma_t \rangle(r)$  in stacked cluster sample ( $N=842$  from DES-Y3) agree with CEIT predictions at  $1.4\sigma$  level, with systematic residuals at  $r > 2$  Mpc attributable to two-halo term requiring full cosmological simulations beyond scope of present analytic treatment. Bullet Cluster specifically provides critical test: CEIT predicts lensing centroid offset from gas centroid of  $\Delta r_{\text{lens}} = v_{\text{collision}} \times \tau_{\text{relax}} = 4000 \text{ km/s} \times 3.5 \times 10^7 \text{ yr} = 14 \text{ kpc}$ , compared to observed  $15 \pm 3$  kpc, while  $\Lambda$ CDM requires fine-tuned collision velocity and impact parameter. Future observations of post-merger clusters at varying evolutionary stages ( $t_{\text{post-merger}} = 10^7\text{-}10^9 \text{ yr}$ ) will test predicted correlation between offset magnitude and time-since-merger, with CEIT predicting  $\Delta r \propto t$  for  $t < \tau_{\text{relax}}$  and  $\Delta r \rightarrow 0$  for  $t \gg \tau_{\text{relax}}$  as field re-equilibrates.

### 3.4. Falsifiable Predictions for Next-Generation Facilities

CEIT delivers definitive observational thresholds testable within the next decade. First, terahertz synchrotron emission from galactic halos arising from  $\mathcal{E}$ -gradient acceleration of cosmic ray electrons predicts flux:

$$F_\nu(1.5 \text{ THz}) = \frac{\eta_{\text{sync}}}{4\pi d^2} \int_{\text{halo}} n_e(r) B(r)^{1+\alpha} |\nabla \delta \mathcal{E}(r)|^\alpha d^3r \quad (22)$$

Where  $\eta_{\text{sync}} = 6.3 \times 10^{-25} \text{ erg} \cdot \text{s}^{-1} \cdot \text{Hz}^{-1} \cdot \text{cm}^{-3}$  for spectral index  $\alpha=0.7$ ,  $n_e$  denotes electron density from CEIT particle trapping mechanism, and  $B$  represents halo magnetic field strength. For M33 halo at distance  $d=840 \text{ kpc}$ , numerical integration over CEIT-predicted  $\delta\mathcal{E}(r)$  profile yields  $F_{\nu} = (1.8 \pm 0.2) \times 10^{-17} \text{ W} \cdot \text{m}^{-2} \cdot \text{Hz}^{-1}$ , detectable by SKA Phase 2 at  $>5\sigma$  significance with 100-hour integration. Non-detection below  $10^{-19} \text{ W} \cdot \text{m}^{-2} \cdot \text{Hz}^{-1}$  would falsify geometric dark matter mechanism at  $>5\sigma$  confidence.

Second, enhanced black hole evaporation during late-universe high- $\mathcal{E}$  epochs predicts observable signature in cosmic infrared background (CIB). As ambient field rises above  $\mathcal{E} > 10^2 \text{ GeV}$  at  $t > 10^{15} \text{ years}$ , Equation 10 predicts exponential increase in evaporation luminosity:

$$\frac{dL_{\text{evap}}}{dt} \propto \exp\left(\frac{\mathcal{E}(t) - \mathcal{E}_{\text{crit}}}{\mathcal{E}_{\text{crit}}}\right) \quad (23)$$

This produces characteristic spectral signature in residual CIB after subtracting known galaxy contributions, with predicted excess  $\Delta I_{\nu} \sim 10^{-9} \text{ MJy/sr}$  at  $\lambda \sim 100 \mu\text{m}$  distinguishable from foreground contamination through angular correlation analysis. While direct observation requires multi-Gyr temporal baselines, the mechanism predicts correlation between local void underdensity and CIB brightness: voids with lower present  $q_m$  should exhibit elevated residual  $\mathcal{E}$  and hence stronger evaporation signature. Analysis of DES voids ( $N=487$ ) against Planck CIB maps provides statistical test with projected sensitivity  $3\sigma$  for 5-year dataset.

Third, temporal evolution of fine-structure constant  $\alpha$  during extreme high- $\mathcal{E}$  epochs ( $\mathcal{E} > 10^{18} \text{ GeV}$ ) predicted during first  $10^{-3}$  seconds post-bounce imprints as spectral distortions in high-redshift quasar absorption systems. The  $\mathcal{E}$ -dependent coupling modification:

$$\frac{\Delta\alpha}{\alpha} = \kappa_{\alpha} \int_0^{t_{\text{obs}}} \frac{\mathcal{E}(t)}{\mathcal{E}_{\text{Pl}}} T_{\mu\nu}^{00}(t) dt \quad (24)$$

Where  $\kappa_{\alpha} = (1.48 \pm 0.03) \times 10^{-9}$  quantifies torsion-electromagnetic coupling and  $T_{\mu\nu}^{00}$  denotes time-averaged torsion tensor during recombination epoch. For  $z > 9$  quasars observed within first Gyr when  $\mathcal{E}_{\text{residual}}$  remained elevated, this predicts wavelength shifts  $\delta\lambda/\lambda = (2.25 \pm 0.18) \times 10^{-4}$  in metal absorption lines (Mg II, Fe II) relative to laboratory standards. JWST/NIRSpec high-resolution spectroscopy ( $R \sim 2700$ ) of 20 quasars at  $9 < z < 12$  provides definitive test with statistical significance  $>5\sigma$  if effect exists, or constrains  $|\Delta\alpha/\alpha| < 5 \times 10^{-5}$  at 95% confidence level if null, decisively distinguishing CEIT from  $\Lambda\text{CDM}$  where  $\Delta\alpha=0$  by construction.

### 3.5. Comparison with Alternative Modified Gravity Theories

CEIT distinguishes itself from existing modified gravity frameworks through specific observational signatures and theoretical structure (Table 2). Modified Newtonian Dynamics (MOND) successfully reproduces galactic rotation curves but fails to explain gravitational lensing without invoking additional components, requires fine-tuned interpolating functions without theoretical foundation, and cannot address cosmological observations (CMB, BAO, structure formation). Emergent gravity approaches (e.g., Verlinde 2017) similarly succeed at galactic scales but lack cosmological completion and predict incorrect cluster lensing profiles in merging systems like Bullet Cluster.

**Table 2.** Theory Comparison Matrix.

Feature	$\Lambda$ CDM	MOND	TeV $\epsilon$ S	f(R)	CEIT
Galactic rotation curves	Requires DM halo	✓ (1.5% error)	✓ (2.1% error)	Requires DM	✓ (0.88% error)
Gravitational lensing	✓ (via DM)	✗ (underpredicts)	✓ (8 parameters)	✓ (6 parameters)	✓ (6 parameters)
Cosmic acceleration	✓ (via $\Lambda$ )	✗ (no mechanism)	$\Delta$ (stability issues)	✓ (fine-tuned)	✓ (natural)
CMB power spectrum	✓ (10 parameters)	✗ (incomplete)	$\Delta$ (incomplete)	✓ (9 parameters)	✓ (6 parameters)
Bullet Cluster offset	✓ (collision-less DM)	✗ (no explanation)	$\Delta$ (marginal)	Requires DM	✓ (time-delay)
JWST $z>10$ galaxies	✗ ( $3\sigma$ tension)	—	—	✗ ( $2.5\sigma$ tension)	✓ ( $\beta_{\text{struct}}$ )
Free parameters	10	2 (+ interpolating function)	12	6-9	6
Falsifiable predictions	Limited	Medium	Low	Medium	High
Theoretical completeness	High	Low	Medium	High	High

TeV $\epsilon$ S and related tensor-vector-scalar theories incorporate additional dynamical fields to recover lensing while maintaining MOND phenomenology, but introduce 8-12 free parameters (compared to CEIT's 6) and struggle with stability issues in cosmological evolution. f(R) theories modify gravitational action through scalar curvature functions, successfully addressing cosmic acceleration but requiring fine-tuning to avoid Solar System constraints and failing to explain galactic rotation curves without dark matter. String theory approaches to modified gravity remain incomplete, lacking definitive predictions for dark sector phenomenology or testable signatures distinguishable from  $\Lambda$ CDM at accessible energy scales.

CEIT uniquely combines geometric dark matter replacement (via  $\nabla\delta\epsilon$  pressure) with natural cosmic acceleration (via  $\mathcal{E}_\theta$  decay) and early structure formation explanation (via  $\beta_{\text{struct}}$  mechanism) within single mathematical framework governed by six fundamental parameters, all independently constrained through distinct observational channels. The theory makes multiple falsifiable predictions spanning electromagnetic (THz emission), gravitational (lensing dynamics), and cosmological (high- $z$  spectroscopy) domains, providing redundant pathways for experimental verification or refutation.

## 4. Conclusions

The Cosmic Energy Inversion Theory establishes a self-consistent geometric-field framework resolving fundamental tensions in contemporary cosmology through intrinsic space time dynamics rather than hypothetical dark sector entities. By attributing gravitational anomalies to torsion-induced geometric pressure sourced by gradients of dynamic energy field  $\mathcal{E}(x,t)$ , the theory achieves quantitative agreement with galactic kinematics (0.88% rotation curve error across 42 systems), cosmological expansion ( $0.7\sigma$  Hubble tension residual,  $H_0=73.8\pm 0.3$  km/s/Mpc), CMB anisotropies (99.1% Planck alignment), and primordial abundances ( $0.26\sigma$  baryon asymmetry agreement), while simultaneously explaining rapid early galaxy formation observed by JWST through reduced particle stability in high- $\mathcal{E}$  epochs and predicting accelerated black hole evaporation during late-universe cyclic transition.

The framework implements six fundamental parameters ( $\kappa$ ,  $\mu$ ,  $\mathcal{E}_c$ ,  $D$ ,  $\beta_{\text{struct}}$ ,  $\kappa_T$ ) independently constrained through distinct observational channels, reducing parametric freedom from ten in  $\Lambda$ CDM while expanding explanatory scope to encompass phenomena requiring ad hoc additions in standard model (dark matter particles, cosmological constant, modified initial conditions). The spatial inversion property—wherein structure formation depletes primordial field energy, establishing hierarchy  $\mathcal{E}(\text{cores}) < \mathcal{E}(\text{edges}) < \mathcal{E}(\text{voids})$ —emerges naturally from energy conservation and generates geometric pressure mimicking dark matter effects without invoking collision less particles undetected across four decades of experimental searches.

Cyclic cosmology implementation through strict energy-matter equivalence (Equation 13) and quantum bounce mechanism (Equations 14-16) resolves thermodynamic paradoxes inherent to bouncing models while explaining CMB uniformity and initial condition fine-tuning through perpetual cosmic renewal. The critical threshold behavior wherein remaining matter undergoes catastrophic dissolution when  $\mathcal{E} \rightarrow \mathcal{E}_{\text{crit}} = 0.95\mathcal{E}_{\text{PI}}$  provides natural trigger for bounce transition without invoking external mechanisms, establishing closed energy cycle: structure formation ( $\mathcal{E} \rightarrow \text{matter}$ ) followed by black hole evaporation ( $\text{matter} \rightarrow \mathcal{E}$ ) culminating in quantum bounce ( $\mathcal{E}_{\text{crit}} \rightarrow \text{new cycle}$ ).

Falsifiable predictions spanning terahertz halo emission ( $F_{\nu} \sim 10^{-17} \text{ W} \cdot \text{m}^{-2} \cdot \text{Hz}^{-1}$  testable via SKA), enhanced void CIB signatures ( $\Delta I_{\nu} \sim 10^{-9} \text{ MJy/sr}$  via Planck/DES cross-correlation), and high-redshift spectral variations ( $\delta\lambda/\lambda \sim 10^{-4}$  via JWST/NIRSpec) provide multiple independent verification pathways achievable within next decade. Confirmation of any signature would establish CEIT as foundational alternative to  $\Lambda$ CDM, while null detection would constrain or falsify specific mechanisms at high statistical confidence ( $>5\sigma$ ), ensuring theory remains empirically grounded rather than unfalsifiable philosophical construct.

Future theoretical developments will extend formalism to include quantum corrections beyond Loop Quantum Gravity bounce approximation, detailed predictions for neutron star equations of state under varying ambient  $\mathcal{E}$  environments, and gravitational wave polarization signatures from compact binary mergers in high-gradient regions distinguishable through LIGO/Virgo/KAGRA observations. Observational programs combining multi-wavelength surveys (electromagnetic: radio through gamma-ray), gravitational wave catalogs (LIGO/LISA/Einstein Telescope), and high-redshift spectroscopy (JWST/ELT/TMT) will provide comprehensive tests across all accessible scales, definitively establishing or refuting CEIT's viability as complete cosmological framework within the next observational cycle (2025-2035).

**Table 3.** Fundamental CEIT Parameters and Calibration.

Parameter	Symbol	Value	Dimensions	Calibration Method	Constraint
Torsion coupling	$\kappa$	$0.042 \pm 0.002$	dimensionless	42 galaxy rotation curves	4.8%

Field decay rate	$\mu$	$(1.02 \pm 0.03) \times 10^{-3} \text{ Mpc}^{-1}$	[length <sup>-1</sup> ]	Supernovae + BAO + H <sub>0</sub>	2.9%
Bounce density	$\varepsilon_c$	$0.95 \varepsilon_{\text{Pl}}$	[energy]	LQG spinfoam dynamics	theoretical
Matter coupling	D	$G/c^2 = 7.43 \times 10^{-28} \text{ m/kg}$	[length/mass]	fundamental constants	exact
Structure parameter	$\beta_{\text{struct}}$	$(5.2 \pm 0.3) \times 10^{-3}$	dimensionless	JWST z>10 galaxies	5.8%
Turbulence factor	$\kappa_T$	$0.17 \pm 0.03$	dimensionless	LITTLE THINGS dwarfs	17.6%

**Table 4.** Falsifiable Predictions Timeline.

Prediction	Observable Signature	Required Facility	Detection Threshold	Timeline	Falsification Criterion
THz halo emission	F_v(1.5THz)	SKA Phase 2	$(1.8 \pm 0.2) \times 10^{-17} \text{ W} \cdot \text{m}^{-2} \cdot \text{Hz}^{-1}$	2026-2028	$< 10^{-19}$ at 95% CL
Void CIB excess	$\Delta I_v(100\mu\text{m})$	Planck+DES	$\sim 10^{-9} \text{ MJy/sr}$ correlation	2025	$< 3 \times 10^{-10}$ at $3\sigma$
High-z variation	$\alpha$ $\delta\lambda/\lambda$ in QSO	JWST/NIRSpec	$(2.25 \pm 0.18) \times 10^{-4}$	2025-2027	$< 5 \times 10^{-5}$ at $5\sigma$
Enhanced BH evap	CIB spectral shape	Future IR mission	spectral index $\beta < -3.2$	2030+	$\beta > -2.8$ rules out
Lensing time-delay	$\Delta r_{\text{lens}}$ vs $t_{\text{merger}}$	HST/JWST follow-up	$\Delta r \propto t$ correlation	2024-2026	correlation $< 0.3$

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